Project Risk Management Based on Analytic Hierarchy Process

Fei-yang DENG¹,²

¹Economics and Management School, Wuhan University, No. 299 Bayi Road, Wuhan, 430072, P.R. China
²Shanghai Data Analysis Center, Construction Bank Corporation, No. 99 Yicheng Road, Shanghai, 200120, P.R. China

Keywords: Risk management, Risk identification, Risk assessment, AHP.

Abstract. In the project construction process, risk is everywhere. To do the project risk management well, it is important to find the project risk factors. How to locate and seize the key factor in various risk factors is an important prerequisite to good project risk management. This article describes the characteristics of project risks and the risk management process, and uses AHP for risk assessment to identify important risk factors and carries out effective control, combined with practical project, and ultimately achieves effective project management.

Introduction

The construction process of the project has many characteristics, such as large amount of investment, large scale, long construction period, complicated technology and high requirements. And in this process, uncertainties and random factors are numerous and constantly changing, and the resulting risks will directly threaten the smooth progress of the project. Risks may lead to a decrease in the economic benefits of the project, which may cause the project to run out of control. Therefore, it is especially important to do a good job in project risk management.

Project Risk and Risk Management Process

Project Risk

Project risk refers to the risk of project loss due to certain uncertainties that may cause the project to deviate from the target during the project life cycle.

The risks of engineering projects have the following characteristics:

1. Risks are diverse and face many types of risks in a project, such as political risk, economic risk, legal risk, natural risk, contract risk, and personnel risk. And there are complex intrinsic links between these risks.
2. The risk is objective, the risk is everywhere and always, and the risk is inevitable.
3. Risks exist throughout the entire project cycle. Risks persist from the completion of engineering decision-making projects.
4. Risk has a certain degree of regularity and is predictable. What is important is that people establish risk awareness, strengthen risk management, and comprehensively control risks.

Project Risk Management

Project risk management means that the project undertaker predicts, identifies, analyzes, and evaluates the risks that may be encountered during the entire life cycle of the project. Based on this, it takes measures and proposes countermeasures to reduce the risk of losses, so as to achieve project target management. Scientific management methods.

Engineering Project Risk Management Process

Risk Identification. Risk identification, as the first step in risk management, includes determining the source of risk, the conditions for generating the risk, the characteristics of the risk, and the conditions for the possibility of risk factors in this project. In this link, you should first be
familiar with the components of the project, grasp the nature of the uncertainties and the relationship between them, analyze the impact of environmental factors on the project implementation process, etc., and use reasonable steps and methods on this basis. Examine various events that may pose risks to the project.

**Risk Assessment and Analysis.** Risk assessment and analysis is what we commonly call “risk assessment”. It uses qualitative and quantitative methods to analyze the identified risk elements in depth, and estimates the probability of risk occurrence and the degree of interference to the project. In addition to this, an objective qualitative assessment of the project's risk level can also be conducted by analyzing and weighing the risk factors.

**Risk Countermeasure Decision.** Risk decision-making is the process of determining the best combination of risk events for construction projects. Risk response measures that have been formulated to address the risk assessment without eliminating or reducing the risk of adverse consequences. When formulating a risk response strategy, it is necessary to combine project objectives and comprehensively consider the degree of risk hazard and risk prevention and control costs. In practice, although different projects have different risk response measures, risk prevention and control have a basic set of strategies, such as risk transfer, risk avoidance, loss control, and risk retention.

**Implementation and Post-Assessment.** After making the right decision on risk, the implementation process is very important. In the implementation process, the implementation status shall be monitored, real-time adjustment of risk prevention and control plans and various management measures to ensure the smooth implementation of the plan. Finally, a comprehensive evaluation shall be made of the effects of the reduction of risks, and the effects and differences of implementation shall be evaluated.

Summarizing the risk factors existing in the project implementation process is an important prerequisite for scientifically conducting risk management and control work. How to deeply tap the key elements of various risk factors is also a top priority of risk management. The project department must first establish a rigorous risk assessment system and use this system to carry out risk assessment on the identified risk factors. Whether the evaluation of risk factors is accurate or objective mainly depends on whether the design of the evaluation system is reasonable or not. The following section will introduce a detailed introduction to the risk assessment indicator system based on the analytic hierarchy process.

**The Basic Principles and Analysis Steps of AHP**

**Analytic Hierarchy Process**

In the mid-1970s, Prof. T.L. Saaty of the University of Pittsburgh proposed a qualitative and quantitative method of systematic analysis-AHP. It is essentially a way of thinking. AHP is an effective tool for analyzing complex management problems. It has “multi-criteria, multi-targets, strong methods, and strong systems. Its structural characteristics and strong practicality have now been popularized in political, economic, scientific research, and other fields. Problems that are difficult to perform qualitative and quantitative analysis in risk management can all be well solved by the analytic hierarchy process.

**Fundamental**

As an analytical method that combines qualitative analysis with quantitative analysis, the essence of it is to arrange an intricate and complicated problem according to the dominance relationship between its constituent elements and elements, and arrange it into a hierarchical structure. After sorting, the final importance of each element is determined by the experienced analysts by sorting and comparing the ranking results.

**Analysis Step**

Using the analytic hierarchy process can be divided into five steps:
**Create a Hierarchy Model.** According to the actual situation, the model can be further subdivided into the program level, the criterion level, and the target level. Complex issues can be divided into the general goal layer, sub-objective layer, criterion layer (or constraint factor layer), program layer, or more hierarchical structure. Determine the objectives of the evaluation, the evaluation plan, and the criteria and indicators of the evaluation to construct a hierarchical model of the system. Then place each work package in the risk identification model to identify and analyze the risk factors, and comprehensively identify the risks. Build a risk analysis hierarchy model for this work package.

**Construction Judgment Matrix.** The relative importance of the elements between the upper and lower layers is determined by experienced technicians using comparative scoring. The AHP is based on the judgment matrix to analyze and contrast the project risks. The construction of the judgment matrix is undoubtedly the most important step in the AHP. Judgment matrix shown in Table 1, the judgment criteria can be carried out in Table 2.

**Table 1. Judgment matrix.**

<table>
<thead>
<tr>
<th>A_k</th>
<th>B_1</th>
<th>B_2</th>
<th>L</th>
<th>B_1</th>
<th>L</th>
<th>B_n</th>
</tr>
</thead>
<tbody>
<tr>
<td>B_1</td>
<td>B_{11}</td>
<td>B_{12}</td>
<td>L</td>
<td>B_{11}</td>
<td>L</td>
<td>B_{1n}</td>
</tr>
<tr>
<td></td>
<td>B_{21}</td>
<td>B_{22}</td>
<td>L</td>
<td>B_{21}</td>
<td>L</td>
<td>B_{2n}</td>
</tr>
<tr>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>B_n</td>
<td>B_{n1}</td>
<td>B_{n2}</td>
<td>L</td>
<td>B_{n1}</td>
<td>L</td>
<td>B_{nn}</td>
</tr>
</tbody>
</table>

**Table 2. Criteria for evaluation criteria.**

<table>
<thead>
<tr>
<th>Score B_{ij}</th>
<th>Definition (B_{ij} is the numerical value of B_i relative to B_j relative to A_k indicated)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B_{ij}=1</td>
<td>The i factor is as important as the j factor</td>
</tr>
<tr>
<td>B_{ij}=3</td>
<td>The i factor is more important than the j factor (slightly important)</td>
</tr>
<tr>
<td>B_{ij}=5</td>
<td>The i factor is more important than j factor (obviously important)</td>
</tr>
<tr>
<td>B_{ij}=7</td>
<td>The i factor are more important than j factor(strongly important)</td>
</tr>
<tr>
<td>B_{ij}=9</td>
<td>The i factor is more important than j factor (absolutely important)</td>
</tr>
<tr>
<td>B_{ij}=2,4,6,8</td>
<td>The comparison of the importance of i factor and j factor is in the middle of the above result</td>
</tr>
<tr>
<td>reciprocal</td>
<td>The comparison of the importance of j-factor and i-factor is the reciprocal of the comparison of the importance of i-factor and j-factor.</td>
</tr>
</tbody>
</table>

**Hierarchical Ordering and Consistency Checking.** Hierarchical ordering is to determine the degree of influence of the elements contained in a certain layer on the elements in the upper level. The principle is: based on the matrix analysis method to obtain the feature vector of the judgment matrix. The degree of interference (that is, the weight value) of an element at the upper level by this layer element is expressed by the feature vector, and the single-order result is the weight value. It is suggested that the square matrix method and the sum-product method be used to calculate and analyze the matrix eigenvectors. The two methods for approximate solution fully meet the design requirements.

1) The elements of B are multiplied by rows and then opened to nth power (n is the order of the judgment matrix), and the geometric mean $W_i$ of all elements of each row of the judgment matrix is obtained.

2) Normalize the set mean $W_i$ to get the weight W.

3) Use the following formula to perform mathematical operations on the largest eigenvalue $\lambda_{max}$ of the judgment matrix, where $(B_w)_{ij}$ represents the i th element of $B_w$.  

616
\[
\lambda_{\text{max}} = \sum_{i=1}^{n} \frac{(B_w)_i}{nw_i}
\]

4) Perform the calculation of the CR value and conduct a consistency check

\[
CI = \frac{\lambda_{\text{max}} - n}{n - 1} \quad CR = \frac{CI}{RI}
\]

In the above formula, RI means “average random one-time indicator” and n means “order matrix” (see Table 3 for details). Assuming CR < 0.1, it is concluded that the consistency of the judgment matrix is acceptable. If the conclusion is negative, then Must re-judge and list new judgment matrix.

Table 3. Mean random consistency indicators.

<table>
<thead>
<tr>
<th>Order</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>RI</td>
<td>0.00</td>
<td>0.00</td>
<td>0.58</td>
<td>0.90</td>
<td>1.12</td>
</tr>
<tr>
<td>Order</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>-</td>
</tr>
<tr>
<td>RI</td>
<td>1.24</td>
<td>1.32</td>
<td>1.41</td>
<td>1.45</td>
<td>-</td>
</tr>
</tbody>
</table>

**Total Ranking.** Through the analysis and calculation of each level, the relative weights of each index are sorted according to the result of the operation. The relative weight of each index or evaluation scheme in the level target is determined according to the weighted result after operation.

**Calculate the Overall Score.** The scores of evaluation plans and evaluation indicators are calculated and weighted averages are obtained after they are entered into the mathematical formula (ie, the overall score), and the highest risk is the highest in the total score.

**Application of AHP in a Project**

**A Project Introduction**

General overview of the project, as shown in Table 4.

<table>
<thead>
<tr>
<th>Project name</th>
<th>XX Building Project Block B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project scale</td>
<td>106783m²</td>
</tr>
<tr>
<td>Project location</td>
<td>Tianjin City XX block</td>
</tr>
<tr>
<td>Construction unit</td>
<td>XX Investment Development Co., Ltd.</td>
</tr>
<tr>
<td>Supervision unit</td>
<td>XX Engineering Supervision Co., Ltd.</td>
</tr>
<tr>
<td>Design unit</td>
<td>XX Residential Architectural Design Institute Co., Ltd.</td>
</tr>
<tr>
<td>Construction unit</td>
<td>XX Construction Engineering Co., Ltd.</td>
</tr>
</tbody>
</table>

The project has the following features:

①The project is huge and the construction technology is complicated.
②The site of the construction site is narrow, and the planning of land use for planning and traffic organization is difficult.
③The project is located in the city center, pay attention to environmental protection and disturbence and civil disturbance.
④The foundation of the project is located on the rock, and the elevation of the bedrock is complex and the construction is difficult.
⑤It is very important for the foundation pit to be excavated too deep, with many surrounding pipelines and to ensure the safety of the foundation pit envelope structure.
Establish a Risk Analysis Hierarchy Model for a Project

Risk identification is the first step in building a model. The purpose of risk identification is to identify the source of the risk, the conditions of occurrence of the risk, the characteristics of the risk, and the risk factors that determine the impact that may have on the implementation of the project. This project adopts the brainstorm method to identify risks, that is, convene relevant conferences to allow experts and engineering technicians to conduct a focused discussion on possible sources of risks and risk factors of the project, and then sum up the conclusions of the conference and build a risk analysis hierarchy model. And the corresponding judgment matrix.

Using the Scoring Method to Obtain a Pairwise Comparison Judgment Matrix (Table 5~Table 7)

<table>
<thead>
<tr>
<th>A_k</th>
<th>B_1</th>
<th>B_2</th>
<th>B_3</th>
<th>B_4</th>
<th>B_5</th>
<th>B_6</th>
</tr>
</thead>
<tbody>
<tr>
<td>B_1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>B_2</td>
<td>1/2</td>
<td>1</td>
<td>1/2</td>
<td>1/3</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>B_6</td>
<td>1/5</td>
<td>1/3</td>
<td>1/4</td>
<td>1/3</td>
<td>1/2</td>
<td>1</td>
</tr>
</tbody>
</table>

Similarly, the parameters of B1~B6 are also compared and analyzed to obtain a similar judgment matrix (abbreviated here).

Apply AHP Method to Get Weight Set

Firstly, calculate the geometric mean corresponding to each row element of the judgment matrix B by the following formula.

\[ w_i = (1.9786, 0.8909, 1.6984, 1.4422, 0.6177, 0.3749)^T \]

Then pass the following formula to W Perform normalized calculations:

\[ w_i = (0.2825, 0.1272, 0.2425, 0.2060, 0.0882, 0.0535)^T \]

Substituting the parameters obtained by the above equation into the following formula to calculate the maximum eigenvalue of the judgment matrix \( \lambda_{\text{max}} \).

\[ BW = (1.7238, 0.7954, 1.4643, 1.3085, 0.5369, 0.3258)^T \]

\[ \lambda_{\text{max}} = 1.7238 + 0.7954 + 1.4643 + 1.3085 + 0.5369 + 0.3258 = 6.1528 \]

Table 6. Summary of calculation of weights for a project construction risk evaluation index.
Table 7. List of risk assessment indicators for building B of XX building project.

<table>
<thead>
<tr>
<th>No.</th>
<th>Risk factors</th>
<th>Weights</th>
<th>Accumulation weight</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>B₃₂ Parts shortage, not supporting</td>
<td>0.0945</td>
<td>0.0945</td>
<td>A</td>
</tr>
<tr>
<td>2</td>
<td>B₃₃ Incomplete contract terms</td>
<td>0.0681</td>
<td>0.1626</td>
<td>A</td>
</tr>
<tr>
<td>3</td>
<td>B₄₄ Low internal communication efficiency</td>
<td>0.0701</td>
<td>0.2327</td>
<td>A</td>
</tr>
<tr>
<td>35</td>
<td>B₂₅ Engineering quality inspection and project acceptance did not meet the required requirements</td>
<td>0.0025</td>
<td>1.0000</td>
<td>C</td>
</tr>
</tbody>
</table>

Then use the following formula to calculate the value of CR and conduct one-time inspection:

\[
CI = \frac{(6.1528 - 6)}{6 - 1} = 0.0306
\]

\[
CR = \frac{0.0306}{1.26} = 0.0242 < 0.1
\]

Meet the consistency test requirements.

Using this principle, the parameters of the judgment matrix B₁~B₆ are calculated and analyzed. Finally, they are sorted according to the weights of the Bij, and the accumulated weights are used as a reference to refer to the risk evaluation indicators. The weighted sorting table categorizes and manages various risk factors.

In project management, the accumulated weights of the statistical risk factors are classified according to levels A, B, and C (for details, see Table 7). Category C falls under the category of “general monitoring targets,” and the cumulative weight is greater than or equal to 0.95. Category B is “the general management target”. The accumulative weight is between 0.8~0.95; Class A belongs to “key control object” and the accumulative weight is basically between 0~0.8.

For the narrow construction site and difficult traffic organization, the general layout was adopted in stages; when the basement construction stage was carried out, the first layer of support beams was reinforced and the steel bar and small wood processing machines and yards were set at the first place. Supporting beams on the floor; processing steel components and other components in different places and transporting them to the site by car.

When there is a shortage of spare parts, it can only be stopped for work. The company has convened a number of meetings to discuss solutions, and several coordinations have been made between the drawing design unit, the supplier and the installation company to ensure the proper division of labor among the various parts. Under their respective duties, at the same time, they have formulated emergency response plans and, in short, have made every effort to ensure the timely supply of materials.

For problems such as deep excavation of excavation, multiple surrounding pipelines, and ensuring the safety of the foundation pit protection structure, the selection of a local qualified design agency to support the design of the support scheme ensures that the design scheme is reasonable, appropriate, safe and reliable. Experts have demonstrated that during the construction of supporting structures, quality process monitoring is performed to ensure the construction quality of supporting structures; a reasonable earth excavation construction plan is prepared to ensure reasonable excavation routes and construction sequences; a monitoring group is assigned to do Good pit support monitoring, regular observations, if found abnormal immediately start the emergency plan to ensure the safety of foundation pit enclosure structure.

Poor communication efficiency within the organization directly affects the execution efficiency of construction tasks. The management department has formulated strict information management procedures for this issue prior to the start of construction of the project. Through the real-time and efficient information management system, the information, such as policies and documents, will be uploaded. In short, the application of the risk control technology of the system makes all the implementation of this project under control.
Conclusion

Through the analysis of this paper, we can see that through the AHP method to predict, analyze, evaluate, and take effective measures for the risks and related influencing factors encountered during the implementation of the project, you can reduce the loss, ensure the smooth progress of the project, and thus effectively manage the risk. However, there are many other factors influencing the project risk. The author only selects several typical factors from the comprehensive analysis, and in practice, it should make a reasonable evaluation in light of the actual situation. The AHP and other decision-making methods can be used. Combining, listing the actual situation of project project risk management, so as to better carry out project risk management.

References